Yosemite Hydroelectric Power Plant
(Cascades Power Plant)
Intersection of State Highways 120
and 140, Continuing North Side
of Highway 120 for 1 Mile
Yosemite National Park
Mariposa County
California

HAER NO. CA-20

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

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Historic American Engineering Record
Division of National Register Programs
National Park Service
Western Region
Department of the Interior
San Francisco, California 94102

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HISTORIC AMERICAN ENGINEERING RECORD

YOSEMITE HYDROELECTRIC POWER PLANT (Cascades Power Plant)
HAER NO. CA-20

Location:	Intersection of State Highways 120 and 140, Continuing North Side of Highway 120 for 1 Mile Yosemite National Park Mariposa County, California U.S.G.S. 15 minute Yosemite, California, quadrangle Universal Transverse Mercator coordinates: A 10. 263715. 4178070; B 10. 263665. 4178105; C 10. 263565. 4178130; D 10. 263400. 4178185
Date of Construction:	1916-18. Major alterations: 1935, 1939
Engineers/Architectects:	J.D. Galloway and A.H. Markwart, Civil Engineers, San Francisco, California .
Present Owner:	U.S. Department of the Interior, National Park Service
Present Use:	Hydroelectric power production
Significance:	The Yosemite Hydroelectric Power Plant is a good example of its type and possesses a high level of integrity. Though once commonplace the type of system utilized by the power plant is becoming rare with intact systems even more rare. There are no other known penstock-fed systems in California with their original Pelton wheels (a particular type of turbine), generators, switch boards, and design intact.
Report Prepared by:	Harlan D. Unrau Historian Denver Service Center, Western Team National Park Service 755 Parfet Street P.O. Box 25287 Denver, Colorado 80225
Date:	July 1986

TABLE OF CONTENTS

INTRODUCTION

The history of Yosemite National Park has been marked by increasing public awareness of its scenic beauty and the resultant rise of visitation. From the time of its first protection as a state property in 1864 through its operation as a unit of the National Park System, development at Yosemite has increased, particularly to accommodate those visitors seeking the modern comforts of electricty, heat, hot water, and restaurant facilities. By 1916, when the National Park Service was established, its director, Stephen T. Mather, had decided that Yosemite had a high priority for development, anticipating future visitation levels and utilization of the Yosemite Valley that would surpass the totals of all past years. The projections by Mather were correct, as visitors to Yosemite have come in increasingly larger numbers during the past seven decades. The early plans by Mather for the development of modern facilities in the park commenced the most extensive construction program in Yosemite. A significant element of that first development was the design and construction of a permanent power plant to meet the electrical demands of Mather's "new Yosemite."

For its important role in the development of Yosemite, the hydroelectric power plant has been determined to have local significance in the park's history. Though not unique at the time of its construction and initial operation, the plant is one of few relatively unaltered systems of its design, type, and output still extant in California. Thus, it has been determined to have regional significance in the field of engineering, because it embodies the distinctive characteristics of a type of power plant representing a particular period in electrical engineering.[1]

NOTES

[1] National Register of Historic Places Inventory--Nomination Form, "Yosemite Hydroelectric Power Plant," Prepared by James P. Delgado, September 25, 1981.

CHAPTER I

HISTORY OF THE YOSEMITE HYDROELECTRIC POWER PLANT

Following discovery of the spectacularly scenic area now incorporated within the boundaries of Yosemite National Park, an increasing number of visitors travelled the dirt trails and roads through the mountains to enjoy the grandeur that eventually qualified Yosemite for preservation as a unit of the National Park System. Through the years, as improved modes of transportation and access roads led to ever growing numbers of visitors, facilities, such as hotels, camps, and other public use accommodations, were planned and constructed to promote visitor enjoyment. These developments were sporadic and haphazard, however, until the establishment of the National Park Service in 1916 and the personal commitment of Director Mather to improve Yosemite with modern permanent facilities. The growing use of automobiles and the intention of Mather to construct a paved highway into the valley, coupled with the increasing popularity of the area, would combine to create ever increasing levels of visitation. To meet the demands of these visitors Mather commenced plans to locate modern facilities in the park.[1]

With the assistance of his brother-in-law, Henry Floy, a prominent New York electrical and mechanical engineer and author of various publications in those fields, Mather planned a permanent hydroelectric plant for Yosemite to be located outside the valley on the banks of the Merced River.[2] Floy prepared a general plan for the system and then aided Mather in lobbying Congress for the necessary funds for its design and construction.[3] Their efforts were supported by the superintendent of Yosemite, who in 1915 had noted that the rising park visitation had created "a marked increase in the use of electricity for power purposes and the time is nearing when the present plant will not be able to supply the demand."[4] Mather and Floy were undoubtedly encouraged in their efforts by Secretary of the Interior Franklin Lane, who later supported the development of hydroelectric power in the United States. He observed that "there is undeveloped in the United States today something like thirty-five million water horsepower."

The personal influence of Mather and the sympathies of Lane, as well as their cogent argument that revenue would accrue to the government through the sale of excess power, persuaded Congress, and on July 1, 1916, the Sundry Civil Expense Appropriations Bill (P.L. 732) authorized the expenditure of $153,850 for a hydroelectric power plant at Yosemite. Mather, pleased with the result, wrote in his annual report for 1916 that the proposed plant

> is now under construction and will be finished by June 30, 1917. . . . It is being constructed with special care so as to be as inconspicuous as possible along El Portal Road. The plant when completed will generate approximately 1,500 kilowatts during high water and approximately 750 kilowatts during the low water in the fall. This will furnish sufficient power for lighting all camps and the new hotel under construction, as well as all the main roads and footpaths in the Yosemite Valley, and for heating and cooking at the hotel and permanent camps.[5]

Construction of the power plant commenced in August 1916 under the supervision of J.D. Galloway and A.H. Markwart, civil engineers of long experience and practice in San Francisco who had taken Floy's general plan and designed the physical facilities in consultation with Mather.[6] The system, as designed by Galloway and Markwart, included a masonry diversion dam, or weir, with an intake, a 5,837-foot wooden penstock, and a reinforced concrete powerhouse with twin Pelton Wheels and generators. The original penstock was to be steel, the common material in use at the time, but for unknown reasons (perhaps the cheaper cost) redwood stave pipe was utilized.

Despite the substitution of the cheaper pipe, however, the original estimates for the construction of the system were soon found to be insufficient. In a letter to the Secretary of the Treasury on January 11, 1917, Interior Secretary Lane asked for an additional $60,000 appropriation for the Yosemite power plant, enclosing a report from engineer Galloway itemizing the reasons for the increased costs.[7] The original site selected for the plant below Vernal Falls was found to be unsuitable, according to Galloway, and a new location near Pulpit Rock was chosen. After site surveys were conducted in August fifty men were hired in September and a camp was built, construction machinery was installed, and specifications for the powerhouse were issued. The first setback to construction occurred in October, when excavations in the river bed for the masonry dam revealed a deep layer of loose sand, thus making such a dam inadvisable. A timber crib dam was substituted in its place, but additional equipment was needed, thus adding to the building costs that were already rising due to lost time. The specifications for the output of the plant were also revised, with a 2,000-kilowatt plant being proposed instead of the original 1,500-kilowatt operation. Another difficulty, according to Galloway, was the expense of labor:

> In 1915 it was possible to obtain plenty of labor at the rate of $2.25 per day of nine hours. Government regulations require an eight hour day and we are at the present time paying $2.75 per day for common labor, with proportionately increased cost for better grades of labor. This was largely brought about by the fact that the City of San Francisco is working on a water supply for that City at Hetch-Hetchy Valley, about 20 miles from us, and is paying $3 per day for common laborers.

The "increased estimate" of $59,860 was also based on other factors. Rising costs for copper wiring and equipment and the rehabilitation and supplement of the existing primitive transmission lines from the old temporary power plant, when coupled with the additional costs of the dam (which totalled $25,000) and a need for more power to meet visitor demands, contributed to the revised estimate. To offset this news, however, Galloway observed that the estimates for the revenues from the power plant would reach some $40,986 per year with an estimated operational cost of $17,300 per annum.

Congress responded with the necessary funds in the Sundry Civil Expense Appropriation Bill of June 12, 1917. A grateful Mather reiterated the need for the additional funds in his annual report for 1917, noting that the "power house has been constructed on the Merced River and may be seen by all visitors entering the park via the El Portal road. It is a structure of simple but attractive design and the materials of construction used were steel and concrete."[8]

The visitation figures for Yosemite continued to climb throughout 1917, supporting Mather's contention that increased visitation would require additional power from the new plant. In his annual report for 1917 (as reported in the Sierra Club Bulletin) park superintendent Washington B. Lewis observed that visitors "to the park during the period October 1, 1916, to September 30, 1917, reached a total of 34,510. . . . The total number of automobile visitors utilizing the free public camps during the season of 1917 was 10,598. This compares with 4,038 for the season of 1916. . . ."[9]

Since increased visitation meant a greater need for the completion of the powerhouse, work was rushed to completion despite a lack of $5,000 to finish the project. Rising costs for materials and labor due in part to the entry of the United States into World War I on April 6, 1917, forced many of the contractors, especially those for the installation of the penstock, to suffer losses ranging between ten and twenty percent. In January 1918 Secretary Lane again appealed to Congress, this time for the $5,000 needed for "construction of the concrete floor of the powerhouse, back filling on the penstock pipe, excavation and concrete work in the tailrace, installation of office partitions and plumbing, setting of powerhouse machinery, and certain incidental items." Lane asked that the money be allocated from the anticipated revenues of the park, stating that it was "hardly necessary to point out that unless the relatively small amount of park revenues that are involved in this authorization is made available the park will lose the benefit of the money already expended on this point, and the valuable structures completed and the equipment installed will be idle in the Merced River Canyon."[10]

Congress again responded, approving the use of the park revenues in the Sundry Civil Expense Appropriations Bill of March 28, 1918. Work was completed in May of that year, and on May 28 the new plant commenced operations. In his annual report for 1918 Mather noted the completion of the power plant and provided a brief description of its components. He observed that the system consisted of

> a long crib diversion dam across the Merced River about a mile below the Pohono Bridge, with concrete head works opening into a 64-inch concrete pipe 400 feet long. This gives into a 54-inch redwood stave pipe which, in connection with a steel pressure pipe of the same diameter, delivers the water to the turbines under a head of 330 feet. The powerhouse is equipped with the highest class of hydro-electric machinery. Two General Electric dynamos of 1,000 kilowatts each are connected with its two Pelton turbines. From here the current passes on a three-phase system to the main distributing point near Yosemite Village.[11]

The new power plant was dedicated formally on September 7, 1918, in ceremonies attended by Mather and Lane and a "distinguished little company." The plant was dedicated in memory of Henry Floy who had died recently. According to Mather this was done since Floy's "voluntary study of the problem, whose report, and finally whose presentation of the proposition before the Appropriations Committee of the House were the factors which principally brought about its realization." In referring to the tremendous increase in visitation to Yosemite Mather stated, "I dwell upon the installation of this plant because in a way it symbolizes the new and greater function for which the Yosemite National Park is preparing, and which it will assume in the very near future."[12]

Ironically, news of the completion of the plant was received happily in San Francisco by the Sierra Club, which several years earlier had expended considerable money and energy in the effort to stop development of the San Francisco water supply system in Yosemite's Hetch-Hetchy Valley. According to park superintendent Lewis, the Sierra Club noted the new power plant completed at a cost of $212,000 which could supply 2000 kilowatts and would "take care of the needs of the Yosemite Valley for a long time in the future."[13]

After three difficult years the long-awaited power plant was completed. In his 1919 annual report Mather described the development of the "New Yosemite" and stressed the need for additional improvements:

> This broader understanding and appreciation of the park became general (sic) even faster than we had dared to hope, although for years we have been looking forward to the time when the people would come to the realization that the Yosemite possesses vastly

> more charms than those of the great valley and its waterfalls, spires, and towering cliffs. We had anticipated a slower growth of the new conception. . . . However, our future course is now definitely marked for all of us. . . .
>
> Funds must be provided by the Federal Government for extensive development . . . while the enterprises engaged in furnishing accommodations of various kinds must enlarge their establishments and better prepare to meet the ever-increasing demand for every type of service.[14]

The Yosemite park staff enthusiastically welcomed the opening of the new power plant. In later years, Jack Emmert, then superintendent of Glacier National Park, recalled his tenure as assistant electrician at Yosemite. Starting work in September 1912 Emmert was responsible for operation of the park's first temporary power plant at Happy Isles, which consisted of "2-75 KVA G-E, 2-Phase 2300 volt generators, belt driven, by two Pelton impulse water wheels, one of which was equipped with a Pelton governor and belt tightener . . . the 2-phase generators were obsolete when I arrived, so that it was difficult to purchase repair parts. . . ." Emmert and the other electricians were pleased with the new permanent plant, which "made Yosemite a most modern electrical area."[15]

While the power plant met the park's existing electrical demands the predictions that it would take "care of the needs of Yosemite Valley for a long time" did not come to fruition as visitation figures continued to climb beyond the expectations of the National Park Service. By 1928 the output of the plant was inadequate for the park's needs. A report to the Federal Power Commission that year stated:

> The capacity of the plant is about 2,000 kilowatts, and the average output around 8,000,000 kilowatts annually. The energy produced is employed to meet part of the requirements of the Park Service and its concessionaires in Yosemite Valley, the remaining demand being met by power received over the transmission line of San Joaquin Light & Power Corporation extending up the canyon to El Portal.[16]

In addition to the increased demand for power the system was plagued by a lack of comprehensive maintenance. In 1935 a report on the system stated, "During its seventeen years of existence, all units, which include

[the] intake chamber, a 54-inch penstock line, 5600 feet in length, two 31-inch Pelton Francis Water Wheels and two 2,000 K.W., G.E. generators, had not experienced a complete and thorough overhaul. . . .[17]

That same year an extensive rehabilitation and repair program was undertaken utilizing Public Works Administration funds and laborers at a total cost of $61,712.67. The work accomplished included replacement and addition of new power lines to Yosemite Valley and two major repairs and additions to the penstock. Of the latter one was installation of an automatic shutdown valve some 500 feet from the beginning of the intake. The reasons for this installation were described by Superintendent Charles G. Thomson:

> . . . the 54-inch woodstave penstock line serving the Yosemite Valley Power House has become with the constant growth of Yosemite National Park, a pertinent problem from the standpoint of the safety of those using the All-Year-Highway [State Highway 140], located just below the line in its entirety of 5,668 feet. The major portion of the location is in country which is subjected to rock and dirt slides of varying proportions. In fact, on four separate occasions in the past 18 years there have occurred major breaks in the penstock line due to rock slides. A total of 270 feet of line has been renewed due to this cause alone. In all instances not only were the lives of tourists endangered, but communication and power facilities were temporarily broken . . . the main entry to Yosemite Valley was either wholly or partially blocked and also faced complete demolition . . . the only means of stopping flow through the line was by a manually operated valve at the intake, which could not be shut down until some Park maintenance man journeyed five miles from Park Headquarters to the dam--a very poor and unsafe condition.[18]

A surge pipe, designed to help equalize the surges and oscillations of water pressure in the penstock when the demand for electricity increased or decreased in the powerhouse, was installed in 1935. The surge pipe proved to be totally inadequate, however, and in 1939 a steel plate surge tower, which is still in use, was installed in its place at the end of the wooden penstock line.[19]

As visitation and electrical requirements continued to rise the demands on the output of the power plant also increased. By the early 1930s it was found to be inadequate for the needs of the park. A bypass line to the San

Joaquin Light and Power Company's (now part of the Pacific Gas and Electric Company) lines was constructed, and whenever the river level was too low to generate power or the demand for electricity in the valley exceeded the capabilities of the plant the bypass line would supply the needed power to the valley. During times of shutdown or equipment failure external electrical power supplied the total needs of the park.[20]

By the late 1930s the power plant was causing major problems. The entire penstock was found to be rotten and unsafe and a new line was required. Earlier in the 1920s the trestles supporting the penstock had been found to be inadequate and were replaced. By 1937 the line had reached a seriously decayed condition, with even a small rock falling against the staves frequently creating a substantial break. Numerous breaks occurred in the line, most of which were associated with major slides on the All-Year-Highway. Deterioration of the shell and woodstaves at the butt joints had progressed to the point that new repairs could not be justified.[21]

Funds for replacing the penstock were advanced to the park in 1938, and in 1939 Civilian Conservation Corps crews began to dismantle the old penstock and install a new line. This work was the first major alteration of the system. The woodstaves were increased to 2-5/8 inches thick, one inch thicker than the original ones. The power lines to the valley, originally strung in "A" frames on and near the line, were re-rigged on high poles. The aforementioned steel surge tank was also installed as part of this work. A small 15 x 18 foot storage shed was built with salvaged staves, 150 feet of rock revetment was laced near the surge tower, and a steel sand trap was installed.[22]

Operations on these improvements began on July 17, 1939, and by the end of the month 500 lineal feet had been constructed. By August an additional 3100 feet had been constructed, and the line was completed on September 26. The total cost of the work was $60,055.93. In 1940 Superintendent Lawrence C. Merriam described the improvements and stated that

> since installation of the new line there have been two cases of falling rocks hitting the woodstaves, each of which would have produced a major repair job and slides on the All-Year-Highway with the old line had it been in place. Only one of these necessitated a replacement of the woodstave, and here the woodstave had not been sufficiently injured to leak a substantial amount of water.[23]

Rock slides and floods, however, caused damage to the system on several occasions during the 1940s and 1950s. A major rock slide in 1943 demolished a 140-foot section of the penstock. The automatic shutdown valve performed well and the water was quickly shut off, thus averting a major slide on the highway. Repairs proceeded quickly, and within one month the system was in full operation.[24] A flood in early 1950 did serious damage to the dam, but the repairs were accomplished quickly. In September of that year, however, more serious deterioration and damage was found in the dam's structure, thus requiring its reconstruction in 1951 at a cost of nearly $33,000.[25] Floods posed serious problems to the powerhouse from time to time, one such occasion occurring in 1955 when the rising waters of the Merced River poured into the structure. To protect the powerhouse from future flooding, stone retaining walls were built on the river banks.[26]

With these exceptions the power plant continued to operate with only minor repairs being undertaken.[27] By the late 1960s, however, the age and deteriorating condition of the penstock and powerhouse equipment began to cause alarm. Demands on the system became more commonplace and the use of external power increased. During the late 1960s and early 1970s major leaks and damage to the wooden penstock began to approach the level of disrepair in the early 1930s.[28] The powerhouse equipment needed constant attention and repair, due in part to operation at lower water levels than those considered advisable by the manufacturer. The decision to divert smaller amounts of water from the river, especially during droughts, led to periods of idle operations, one such occurrence being in 1977 when a drought shut the powerhouse down for four months.[29]

In 1980 the system was examined by hydroelectric engineers who were impressed with the age, integrity, and design of the plant but felt that the time for a major rehabilitation and modernization effort was necessary.

Several problem areas were identified: unsafe wiring, overloaded equipment, inadequate water consumption, rotting and unsafe condition of the penstock, and complete failure of the automatic shutdown valve. It was estimated that the rehabilitation project would cost $4,600,000.[30]

As if to underscore the findings of this report a rock fall in March 1981 punctured the penstock, and a major rock slide resulted from the water gushing from the damaged section. Erosion of the soil underneath the penstock caused the ground to slip away, leading to a collapse of a sixty-foot section of the penstock and closing the All-Year Highway for a 24-hour period. Unlike past damage to the system, however, the new break could not be repaired immediately because of loss of ground on which the penstock supports rested. Repairs would necessitate a replacement section of the penstock supported by a steel truss bridge where there was no longer ground to support the penstock and installation of a new automatic shutdown valve.[31]

The National Park Service prepared an environmental assessment on the hydroelectric power system in May 1982. According to the document the system was "no longer functioning efficiently because of component deterioration." Therefore, it needed frequent maintenance to keep it in operation. The "deteriorated condition of the power system" contributed "to its unreliability," and the "continual maintenance of its components" was "dangerous because of the lack of safety features." In good condition the system could produce enough electricity to meet approximately 65 percent of the demand in Yosemite Valley and would produce excess power that could be sold to the Pacific Gas and Electric Company during the winter and spring.[32]

NOTES

[1] Carl Parcher Russell, One Hundred Years in Yosemite (Berkeley and Los Angeles, 1947), pp. 166-71.

[2] American Institute of Electrical Engineers Year-Book, October 1, 1907, p. 77, and American Institute of Electrical Engineers Year Book, 1915, p. 161.

[3] Robert Shankland, Steve Mather of the National Parks (New York, 1951), pp. 252-53.

[4] "National Parks," Sierra Club Bulletin, IX (January, 1915), 318.

[5] "Annual Report of the Superintendent of National Parks," 1916, in Reports of the Department of the Interior, 1916, pp. 762-63.

[6] For a history of the construction of the hydroelectric power system see "Report On the Yosemite Power Plant, With Consideration Of Design, Cost, and Preliminary Estimate of Revenue," December 6, 1916 [Galloway & Markwart, Guy L. Bayley, engineers], in U.S. Congress, House, Committee on Appropriations, Electric Power Plant, Yosemite National Park, 64th Cong., 2d Sess., 1917, H. Doc. 1940, pp. 3-11.

[7] Lane to Secretary of the Treasury, January 11, 1917, ibid., pp. 1-2.

[8] "Annual Report of the Director of the National Park Service," 1917, in Reports of the Department of the Interior, 1917, pp. 60-61.

[9] "National Park Notes," Sierra Club Bulletin, X (January, 1918), 370.

[10] Lane to Secretary of the Treasury, January 17, 1918, in U.S. Congress, House, Committee on Appropriations, Hydroelectric Power Plant in

Yosemite National Park, 65th Cong., 2d Sess., 1918, H. Doc. 845, pp. 2-3.

[11] "Annual Report of the Director of the National Park Service," 1918, in *Reports of the Department of the Interior*, 1918, p. 45.

[12] *Ibid*.

[13] "National Park Notes," *Sierra Club Bulletin*, X (January, 1919), 476-77.

[14] *Annual Report of the Director of the National Park Service*, 1919, p. 62.

[15] "Yosemite Power Plant & Telephone System (Around 1912-1914)," by J.W. Emmert, February 13, 1958. A copy of this document may be found in the Yosemite National Park files. Copies of all manuscript/archival materials cited in this study may be found in the Yosemite National Park files.

[16] U.S. Federal Power Commission, *Report to the Federal Power Commission on the Water Powers of California* (Washington, 1928), p. 124.

[17] "Final Report, Electric System Extensions and Improvements, Federal Project No. 61--Account No. 408."

[18] *Ibid*.

[19] Memorandum for Superintendent Merriam, H.L. Crowley, May 11, 1939 (and enclosures), and Memorandum for the Regional Engineer, Region IV, Leonard L. Kohl, August 20, 1939.

[20] Memorandum to Colonel Thomson, George D. Burr, Associate Engineer, October 15, 1931, and "Report to Superintendent C.G. Thomson on Power Lost in Transmission of Electrical Energy Purchased from the San Joaquin Light and Power Corporation from Yosemite National Park Plant to Consumers' Meters," George D. Burr, Associate Engineer, September 23, 1931.

[21] Redwood Manufacturers Company to Kittredge, April 2, 1937.

[22] Acting Regional Director, Region Four to Superintendent, Yosemite, January 20, 1953.

[23] Yosemite National Park, California, "Final Report, Replacement of 54" Woodstave Penstock," Lawrence C. Merriam, Superintendent, September 1940.

[24] U.S. Department of the Interior, National Park Service, Yosemite National Park, California, "Final Construction Report, Repairs to Power House Penstock," by H.S. Shilko, Park Engineer, May 1943.

[25] Acting Regional Director, Region Four to Superintendent, Yosemite, January 20, 1953.

[26] Power House Reports, 1955.

[27] Power House Reports, 1951-61.

[28] Power System Statements, Cascades Power Plant, 1966, 1971, 1975.

[29] Hydro-Triad, Ltd., Lakewood, Colorado and Protrans Consultants, El Paso, Texas, "Yosemite Hydroelectric Power Plan Rehabilitation Study," December 1980, and Hydro-Triad, Ltd., Lakewood, Colorado and Protrans Consultants, El Paso, Texas, "Yosemite Hydroelectric Power Plant Rehabilitation Study," June 1981.

[30] Mariposa Gazette, March 12, 1981; Fresno Bee, March 10, 12, 1981; Assistant Manager, Alaska/Pacific Northwest/Western Team, DSC to Regional Director, Western Region, April 15, 1981; and Acting Chief, Maintenance Division to Associate Director, Management and Operations, July 13, 1981.

[31] U.S. Department of the Interior, National Park Service, Denver Service Center, Environmental Assessment, Hydroelectric Power System, Yosemite National Park, California, May 1982.

CHAPTER II

COMPONENTS OF THE YOSEMITE HYDROELECTRIC POWER PLANT

The Yosemite hydroelectric power plant is a good example of its type and possesses a high level of integrity. It varies little in design, capacity, and function from contemporary hydroelectric power systems. Beginning in the 1880s the use of penstocks, or pressurized electricity had become commonplace and thousands of these systems had come into existence by 1916. During the period after 1912 innovations such as the use of large impounded bodies of water (as exemplified by San Francisco's Hetch-Hetchy system, the contemporary neighbor of the Yosemite system) were being used. However, this type of system was not adaptable to low level Sierra streams such as the Merced River which the Yosemite system taps. Though once commonplace the type of system utilized by the Yosemite hydroelectric power plant is becoming rare, with extant intact systems even more scarce. There are no other known penstock-fed systems in California with their original Pelton wheels (a particular type of turbine), generators, switch boards, and design intact.

The Yosemite hydroelectric power plant has seven major design features or components, only one of which was not part of the original system--the steel surge tank added in 1939. It is important to note that the changes to the system have generally been easily reversible additions, such as the log boom at the intake, the electric motors on the turbine wicket gate valves, and the 2,500-k.v.a. transformer in the warehouse. Some replacements have taken place, such as the 1939 replacement in kind of the wooden penstock and the previous and later repairs and replacement of damaged sections, cradles, and trestles. These replacements, however, were generally accomplished with the historic material and method of construction. Some limited changes have taken place, such as the rerouting and restringing of the 11,000-volt transmission line and the addition of the steel surge tank. These changes, however, have been few and essential to the continued and evolving history of the system.[1]

The seven major components of the Yosemite hydroelectric power plant will be discussed in detail. They are the: (1) diversion dam; (2) intake and screens; (3) penstock; (4) surge tank; (5) powerhouse; (6) powerhouse equipment; and (7) main transmission line to the valley.

1. Diversion Dam

The first component of the power plant to be constructed was the diversion dam. Completed in early 1917 the dam, a timber crib structure, is 170 feet long and spans the Merced River at the intersection of State Highway 140 and Big Oak Flat Road in the lower Yosemite Valley. Anchored to a substratum of gravel some eighteen feet below the water and sand of the river by sheet piles, the dam is built of "cribs" formed by logs or square timbers spiked together which are filled with boulders and rocks and sheathed with butt-edged rough-hewn redwood boards. The dam is flanked by two concrete abutments, both of which are about thirty feet high. The crest height of the dam is seventeen feet, four inches. The dam impounds some of the water in an area of roughly two hundred square feet. Much of this water gently flows over the flat crest and then down the slope, running over a concrete sill and an area of consolidated stone and concrete before reentering the river channel. A narrow spillway or gate to the south of the dam's center allows a slightly larger volume of water to escape, forming the main flow to the river course. The northern abutment houses the intake, screens, and beginning of the penstock line. [2]

The dam has not undergone any modifications. Deterioration and occasional flood damage, however, have necessitated repairs and partial replacements. The most notable repairs took place in 1951 to correct severe damage that occurred the previous September when some of the rotten facing boards gave way, thus allowing the water to escape and creating a large hole some five square feet in size. The hole was repaired, but in the process the park staff observed that all of the dam's facing boards were largely rotten and many of the spikes holding them in place had rusted and fallen. The holes were patched temporarily with concrete. [3]

In 1951 an $84,000 reconstruction program was proposed that would have included excavation of accumulated sand and gravel from the impoundment area and allowed for the almost complete diversion of the river into the penstock during periods of low water.[4] The program was not carried out, but the wooden facing of the dam was renewed with rough redwood timbers. Periodic replacement of rotten facing boards has been undertaken, the latest such work taking place in early 1981.[5]

2. Intake, Screens, and Screen House

The intake, screens, and screen house are located at the north abutment of the dam on the roadside of State Highway 140. The intake is a square concrete opening at water level on the east face of the abutment and is covered by a "grizzly"--a series of vertically-spaced steel bars three inches apart. Logs and other floating debris of great size are kept from this screen by a series of logs chained together around the intake, thus forming a "log boom." Originally the boom was the only means of debris exclusion for the system. It proved to be inadequate since debris smaller than three inches was passed directly into the penstock and then into the machinery. This problem was solved in 1928 with the installation of a rotating screen for small objects located atop the abutment and now housed in a wood frame screen house.[6] The screen, which reaches into the water inside the intake, is a "Rex Traveling Water Screen"--a rotating screen made up of one-half-inch wire mesh panels which are connected by a chain and sprocket mechanism driven by an electric motor. As the screen panel in the water becomes clogged, it is elevated in the screen house by the operator using a manual switch. The panel is then manually cleaned and the debris swept through a hole in the floor into the river. A flush valve at the base of the abutment discharges sand and small gravel not caught in the screens back into the river.[7]

The screen house, built in 1945 at a cost of $1,800, is located atop the reinforced concrete abutment that forms its floor and foundation. A single-story wood frame structure constructed roughly in a "T" shape, the structure contains 334 square feet of floor space. The walls are wood siding covered with split wood shingles painted brown. The flat windows, arranged in one, two, and three bays on the various facades, have a plain wood surround and sloping wooden lug sills. The windows are fixed wooden sash with nine lights. There is only one doorway which is located on the north facade and has a plain wood surround. The door is solid wood and hinges inward. The cross-gable roof consists of wooden shingles. There are heavy support beams forming brackets at the gable ends at the peak and eaves, and exposed rafters with end boards are attached at the gable ends. There is a plain wooden frieze board. The style of the structure is essentially utilitarian with some craftsman elements. The interior is open with finished walls and a painted plywood ceiling. The screen is located at the head of the "T" in the corner of the room. Behind the screen is a water-level indicator that provides a reading of the intake's water surface elevation to the powerhouse operator. A hand-operated gate valve closes the intake when necessary. The building is equipped with telephone, electricity, and a portable electric heater.

Outside the building the edges of the abutment have a tubular metal railing that begins at the road and extends around the screen house. There have been no known modifications to the screen or screen house, and the only alterations to the abutment have been the installation of the screens, screen house, and cutting of the flush valve on the base of the south facade.[8]

3. <u>Penstock</u>

The penstock is the conduit that transports water under pressure to the power plant. It begins just past the intake and screens in the north abutment of the diversion dam. As designed and constructed during 1917-18 the penstock is divided into three components--a 66-inch diameter concrete section, a 54-inch diameter wooden stave section, and a 42-inch diameter riveted steel section. The concrete section is buried as are portions of the steel line. The wooden stave portion runs exposed along the contour of the hillside and is supported by wooden and rock cradles, trestles, and an earth and stone bed.[9] There are various manholes and air valves in the wooden line which was completely replaced in 1939.[10] Additions to the penstock include an automatic shutdown valve and house, a steel trap, and a steel plate surge tank.

The concrete 66-inch diameter section of the penstock begins at the intake and extends underground some 343 feet below State Highway 140, surfacing on the north side of the roadway and connecting to the woodstave penstock. A storage shed, located on a wooded slope below trestle No. 9 and the sand trap, was built in 1940.[11] It is a single-story, rectangular wood frame structure with a concrete pier foundation. The walls consist of vertical sections of penstock staves, thus creating a board and batten-type siding. The flat windows, of which there are two on the building sides, have a plain wood surround and wooden slip sills. The windows are fixed wooden sash with nine lights. The doorway on the north facade has a lintel and a plain wood surround formed by sections of penstock staves. The door, which may be a modern addition, is wood-paneled and hinges outward. There is a straight approach wooden stoop without railings. The gabled roof is formed of vertically-arranged staves with a crest board of staves on the peak. There is a wooden water course and exposed rafters with endboards attached at the gable ends. The style of the structure is utilitarian. The interior is open with a wooden floor and unfinished walls. There is no ceiling and no utility connections. Used steel hoops, bolts, wood, and tools are stored in the building.

The automatic shut-down valve, no longer operational, is housed in a wood frame structure alongside and atop the wooden penstock some 500 feet west of its beginning point at State Highway 140. The valve, installed in 1935 at a cost of $7,419.56, was designed and built by the Pelton Water Wheel Company of San Francisco, the same company that had furnished the power house turbines in 1918.[12] The completion report stated that "the valve is held in a normal open position by means of a hydraulic cyclinder with piston attached to lever on the shaft of the butterfly valve, and on which there is mounted a dead weight opposing the force of oil pressure below the piston in the hydraulic cylinder if reduced. . . . Normal operation of the valve is governed by means of a flow activated pilot valve which in turn is controlled by pilot tube connections. . . . The control valve is a three-way siphon bellows tube, differential pressure operated pilot valve designed so that under normal conditions the valve admits pressure to the cylinder, opening the butterfly valve and holding it so." If too much pressure came through the line, or too little as would happen in a break, the oil pressure would drop and the valve would close in 3½ minutes. The last known operation of the valve was in 1943. It has apparently not worked since then and is now chained open with many parts either missing or vandalized.

The valve housing is a one-story wooden frame structure having 53 square feet of floor space. Located alongside and atop the penstock the bottom frames simply rest on the rock surrounding the penstock and the penstock itself. There is no doorway, but a section of wall lifts out to provide access. This section is currently dislodged and lies on the rocks below the penstock. There are no windows, and the gabled roof is covered with composition paper. The style of the structure, which has exposed rafters, is utilitarian. The interior is unfinished and has no floor. An electrical light fixture in the structure is not operable.[13]

The steel sand trap, located atop trestle No. 10 between steel elbows Nos. 1 and 2, was installed in 1939 when the penstock was replaced. The trap is a 52-inch diameter, 11-foot, 5-inch-long section of steel pipe with an underlying "T" valve and trap, operated manually to release accumulated sand and silt. On the hillside below is a low, rough-faced, random-coursed granite wall that diverts the released water from the storage shed located below the sand trap.[14]

As aforementioned the present wooden penstock was built in 1939. Sections have been replaced after damage and deterioration, the most noteworthy repair effort occurring after a rock slide carried away 140 feet of the penstock and 100 feet of trestle on March 19, 1943. The missing sections were replaced by April 16 of that year at a cost of $2,660. All repairs were done in the original manner of construction, the replacement section of penstock being supplied by the contractor for the 1939 penstock--the Redwood Manufacturer's Company of San Francisco.[15] The penstock was shut down in January 1981 by a rock slide that carried away some 100 feet of penstock between trestles Nos. 13 and 14.[16]

The existing condition of the penstock is poor. Numerous leaks and patches are apparent as are a large number of rotten staves and rusted butt joints, some of which are working loose or missing. The penstock wood has dried in various places, causing some of the staves to warp and crack. During a preliminary recharging of the line to the area of the March 1981 break dozens of major leaks were observed. The condition of the penstock is strikingly similar to that described in a 1937 memorandum outlining the need for a replacement.[17]

As discussed earlier the penstock has steel portions. Three of these are short sections of 52-inch diameter riveted steel elbows located at sharp bends of the terrain where the wood could not be gently curved. The elbows are in good condition, although elbow No. 3 has shifted and is held in place by a one-inch steel cable anchored to a large rock on the hill above. There is also a 42-inch diameter steel penstock that begins some 600 feet from the powerhouse at the end of the wooden penstock. The original steel penstock at this location was a single line that dropped down the hillside (a drop of 336 feet to the powerhouse) and branched into the powerhouse turbines. Portions of this riveted steel penstock remain, but sections have been replaced. In addition, there is now a steel "Y" branch at the beginning of the steel penstock leading to the surge tank. This "Y" branch was installed in 1939 along with a 42-inch shut-off valve which is no longer operable.[18] The steel penstock which is in good condition is anchored with concrete and mortared stone cradles, but some portions are underground, primarily the last 100 feet that passes below State Highway 140 and enters the powerhouse.

4. Surge Tank

The surge tank, a reinforced concrete and steel plate structure some forty feet up the slope from the beginning of the steel penstock, was built in 1939 to "damp out" oscillations in flow and water surges caused by operating variations of the turbines. The surge back into the penstock caused "knocking" and "swelling," thus threatening the structural integrity of the building. To prevent the lines from bursting the first surge damping feature was a vertical steel pipe of unknown size and diameter at the beginning of the steel penstock. By 1933, however, this pipe had rusted severely and had lost considerable structural integrity. On February 27, 1935, a new surge pipe was installed (at a cost of $1,355.74) at the original location and consisted of a 24-inch diameter, 50-foot tall steel pipe. This structure did not meet the needs of the system, however, and in 1938 a large steel surge tank was designed by National Park Service engineers and funded for construction in 1939 at the time when the new wooden penstock was to be installed.

The surge tank stands unaltered today. A 42-foot steel line 42 inches in diameter climbs the slope and enters the bottom of the tank. This pipe is supported by mortared rock and reinforced concrete braces. The tank is supported on an octagonal reinforced concrete platform 10½ inches thick with each side of the octagon being 9 feet, 1-3/8 inches wide. The platform is supported by reinforced concrete cross beams 2 feet, 8 inches thick that are supported by five one-foot, eight-inch square reinforced concrete columns on deep footings. The steel tank is eighteen feet in diameter, 29 feet, 6 inches high, and has a conical steel roof. A steel ladder is riveted on one side and a steel gauge on the other. The concrete and steel are painted in their original dark green.

The wooden penstock was completed on October 5, 1939, before the surge tank. To operate the system a round steel plate was bolted over the open end of the "Y" branch that would lead to the tank. When the tank was completed in October the round plate was removed and the surge tank connected. The round steel plate now lies on the ground next to the "Y" branch along with other abandoned fittings, steel loops, unused butt joints, and wood.

The surge tank has performed well and eliminates any oscillating and vibrations in the penstock. It is in good condition, although there is some exfoliation and minor corrosion.[19]

5. Powerhouse

Constructed in 1917-18 the powerhouse is located approximately one mile west of the diversion dam on the north bank of the Merced River alongside State Highway 140.[20] The building is on a lower grade than the highway, and high boulders and trees combine with the lower grade to hide much of the powerhouse from view. A narrow one-way drive leads from the highway to the powerhouse some fifty feet away. The single-story powerhouse is rectangular with 2,000 square feet of floor space and is a reinforced concrete structure with a reinforced concrete foundation. The walls are unpainted concrete. There are two belt courses, one of which serves as a watercourse and as the bug sill for the windows. The flat windows are arranged in three bays on the sides, three bays in the rear, and two windows flanking the centrally-located main entrance on the front facade. The side windows and the central window in the rear have concrete spandrels which have recessed panels and a circular decorative motif. The windows are pivotal metal sashes, arranged in various patterns of six or eight lights.

The doorway is a round head arched opening surrounded by raised concrete coins in an Italian Renaissance motif. This decorative surround supports a concrete entablature. On the surround flanking the door are two bronze rectangular plaques with rusticated frames placed during the dedication ceremonies on September 7, 1918. One dedicated the plant to National Park Service Director Mather's brother-in-law Henry Floy, a New York electrical and mechanical engineer who designed the system concept, while the other is a formal building plaque listing the dates of funding and construction and the names of the contractors and government officials.

The wood door is a horizontal overhead sliding door with Italianate panels, one of which is an individual access door which hinges outward. There is a fanlight above the flat doorway infilling the arch.

The structure has exposed rafters with endboards attached and a plain wooden frieze. The low-pitched gable roof is of wood with a ribbed metal clad finish. The style of the building is utilitarian with Italian Renaissance elements. The interior is a single open space with the exception of two small tongue-in-groove wooden and glazed enclosures in the southeast and southwest corners, one serving as a latrine and the other as an office. The floor is a concrete slab, the walls are concrete, and the open ceiling shows the steel truss supports for the roof.

At the spandrel level is a sliding overhead iron lifting beam chain with a hoist having a capacity of 28,000 pounds. The mechanism was manufactured by the Cyclops Iron Works of San Francisco.[21]

Below the structure the steel penstock enters and bifurcates into two 24-inch-diameter branches beneath the turbines. At the same level is the opening to the turbine housing and a tailrace from which the water passes through a mortared rock and reinforced concrete channel some ten feet wide and thence into the river. A wooden beam bridge spans this channel, located on the south facade. Alongside the plant on the inner banks are mortared granite rough-faced random coursed revetments. The walls were originally built in 1918, but after the powerhouse was flooded in 1955 the walls were raised some five feet to their present level.[22] A concrete-filled sandbag wall was installed at the west end of the tailrace channel in 1956.[23] There are various chain-link enclosures around the powerhouse with transformers and relays, most of which were installed between the 1930s and the 1950s, and the chain-link enclosures were installed in the early 1960s. The powerhouse, revetments, and enclosures are in excellent condition.

6. Powerhouse Equipment

All of the original electrical generation and switching equipment in the powerhouse is intact.[24] Repairs have taken place, particularly on the Pelton wheels. Until the 1950s the repairs were made by the original contractor by the exact reproduction of the original worn or damaged parts. Thus, the repairs have not altered the integrity of the equipment. Additional equipment has been installed, such as electric motors on the wicket gates of the turbines, the 2500 k.v.a. transformers, and some modern gauges on the switchboard, but these components are easily reversible.

The powerhouse equipment is composed of two 31-inch diameter horizontal shaft Pelton-Francis turbines manufactured by the Pelton Water Wheel Company of San Francisco. These turbines, commonly called Pelton wheels, were once generally used, but they are increasingly hard to find, particularly in largely unaltered condition. The Yosemite power plant turbines are fed by the penstock, which bifurcates beneath the powerhouse floor into two 24-inch diameter lines, each of which leads into the turbine. The water flows under pressure up into the scroll case that houses the turbine runner, a Pelton water wheel, causing the runner to rotate. The water then passes through a draft tube in the floor and out the tailrace. The amount of rotation (and hence water) is controlled by governors manufactured by the Pelton Water Wheel Company and wicket gate mechanisms that regulate the turbine operation in response to the demand for electricity. The turbines are each rated at 1,500 horsepower with a maximum efficiency of 83 percent and produce 1,000 kilowatts under the best operating conditions. The turbines, particularly the runners, are in poor condition.

Each turbine is connected to a 1,250-kilowatt (2,300 volts) General Electric generator by a horizontal shaft. The generators rotate at 750 r.p.m and have a five-foot flywheel. Their normal output is 1,000 kilowatts at a 0.8 power factor, and their normal two-hour output is 1,400 kilowatts at a 0.9 power factor. The coils on both generators have been rewound at least once. The generators are unmodified and are in poor condition.[25]

In front of the turbines is the original black slate switchboard (which is badly cracked) with its original dials, switches, and gauges. There are several modern gauges and switches on the switchboard, which has an open back. To the rear of the switchboard in the northeast corner is the original battery-operated emergency start-up. There are original controls and recording devices throughout the plant. None of the equipment operates well, and most of the components are in poor condition. Overheating of the equipment is a common complaint. Most of the electrical wiring has been replaced throughout the powerhouse.

One feature of the powerhouse--a 2,500 k.v.a. transformer manufactured by the Hill Transformer Company of San Carlos, California--is not original. The transformer, located in the northeast corner of the powerhouse, was installed in 1957 to handle incoming power from the Pacific Gas and Electric Company.[26] It is a three-cycle, oil-filled, self-cooled, class OA, 60 cycle, 12470/7200 V Wyp, to 2400 V Delta with taps at 13095, 12785, 12160, 11850 V and at full capacity, core form, 55°C temperature rise model.

In the 1930s the powerhouse output was found to be insufficient for the growing needs of the park; thus provision was made to tap power from the San Joaquin Light and Power Company, since merged into the Pacific Gas and Electric Company. The present transformer is one that was installed to handle this external power. It has performed well despite a 1962 failure caused by a lightning strike.[27] The original aluminum and glass insulation was melted and the transformer removed to San Carlos, where the original contractor rewound the coils with new copper and paper insulation. The transformer was reinstalled in the powerhouse on March 27, 1962, and has operated well since that date.[28]

7. Transmission Line

As designed and constructed in 1918 the 11,000-volt transmission line into Yosemite Valley was strung along and atop the penstock on light wooden "A" frames. The frames were toppled frequently and the line broken during the slides that damaged the penstock. The wires were replaced, and a new line was strung from wooden poles imbedded in mortared stone bases in 1939.[29] The poles were placed along the penstock some 4,000 feet from where they went down the hill, crossed and followed State Highway 140, and entered the powerhouse. This line is still utilized, although some of the rotten poles have been cut down and new poles imbedded in concrete alongside them. Present plans call for a new underground transmission line, thus closing down the present line.

NOTES

[1] National Register of Historic Places Inventory--Nomination Form, "Yosemite Hydroelectric Power Plant," September 25, 1981.

[2] Classified Structure Field Inventory Report, "Diversion Dam," [1975].

[3] E.C. Smith, Park Engineer to Superintendent, September 14, 1950.

[4] James Francis Milestone, "The Influence of Modern Man on the Stream System of Yosemite Valley" (unpublished M.A. thesis, California State University, San Francisco, 1978), p. 98.

[5] "Yosemite Hydroelectric Power Plant Rehabilitation Study," June 1981.

[6] Acting Regional Engineer, Region Four to Superintendent, Yosemite, January 20, 1953.

[7] "Rex Traveling Water Screens," n.d., and Acting Regional Engineer, Region Four to Superintendent, Yosemite, January 20, 1953.

[8] Building Data Form, "Screen House," November 1950.

[9] "Specifications Covering Construction of Trestles and Tramway for Flow Line Pipe Together With Instructions to Bidders, Short Form Agreement and Bond For An Hydro-Electric Power Plant At Yosemite Valley, California," Galloway & Markwart, Engineers, Guy L. Bayley, Associate, July 1917.

[10] Yosemite National Park, California, "Final Report, Replacement of 54" Woodstave Penstock," September 1940, and Redwood Manufacturers Company to National Park Service, October 14, 1938.

[11] Yosemite National Park, California, "Final Report, Replacement of 54" Woodstave Penstock," Lawrence C. Merriam, September 1940.

[12] "Final Report, Electric System Extensions and Improvements, Federal Project No. 61--Account No. 408, [1935].

[13] Building Data Form, "Shelter for Automatic Valve," n.d.

[14] Yosemite National Park, "Sand Trap," April 28, 1939.

[15] U.S. Department of the Interior, National Park Service, Yosemite National Park, California, "Final Construction Report, Repairs to Power House Penstock," May 1943.

[16] Binnewies to Superintendent, February 12, 1980.

[17] Redwood Manufacturers Company to Kittridge, April 2, 1937.

[18] Yosemite National Park, "Wye-Jct. Steel Penstock and Woodstave Pipe," April 28, 1939.

[19] Memorandum for Superintendent Merriam, H.L. Crowley, Acting Regional Director, May 11, 1939; Memorandum for the Regional Director, Leonard L. Hohl, Assoc. Engineer, Region IV, May 8, 1939; Memorandum for the Regional Engineer, Region IV, Leonard L. Hohl, Associate Engineer, May 10, 1939 (and enclosed surge tank specifications); and Memorandum for the Regional Engineer, Region IV, Leonard L. Hohl, Associate Engineer, Region IV, August 20, 1939.

[20] Data on the powerhouse may be found in Building Data Form, "Power House," March 1952, and Classified Structure Field Inventory Report, "Power House," July 31, 1975.

[21] Ibid.

[22] John C. Preston, Superintendent to M.L. Crum, Division Electric Superintendent, November 19, 1956.

[23] Ibid.

[24] Department of the Interior, National Parks, "Specifications Covering Hydro-Electric Equipment Together With Notice to Bidders, Instructions to Bidders, General Conditions, Specific Conditions, Proposal, Agreement and Bond," September 1916.

[25] Detailed information on the history, development, and components of water wheels may be found in The Pelton Water Wheel: A Marvel of Energy & Power of California's Most Illustrious Invention (San Francisco, 1890), pp. 1-59, and Pelton: Bulletin No. 26, Standard Water Motors and Wheels (San Francisco, 1931), pp. 1-8. Further data on the turbines and generators may be seen in P.C. Jacobson, Engineer, San Francisco Service Shop to Charles F. Hill, Chief Clerk, October 23, 1945, and G.V. Arata, Manager, Sales-Service to Lloyd W. Seasboltz, Electrical Supervisor, May 31, 1957.

[26] Luther T. Peterson, Jr., Park Engineer to L.N. McClellan, Assistant Commissioner and Chief Engineer, March 29, 1957.

[27] Electrical Engineer, Region Four to Regional Chief of Operations, Region Four, March 16, 1962.

[28] Electrical Supervisor to Assistant Park Engineer, Yosemite, March 29, 1962.

[29] Yosemite National Park, California, "Final Report, Replacement of 54" Woodstave Penstock," Lawrence C. Merriam, Superintendent, September 1940.

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